INCREASING THE EFFECTIVENESS OF THE NICOTINE INSECTICIDAL UNIT CHARGE[1]

BY EDWARD R. McGOVRAN

NICOTINE RESEARCH FELLOW, RUTGERS UNIVERSITY, 1927–1928.

INTRODUCTION

Thoughtful analysis of the problem indicated in the title of this paper gave the writer reason to believe that the insecticidal efficiency of the nicotine unit could best be increased through the introduction of that substance, when carried in an aqueous solution, into the breathing system of insects against which it is normally used as a spray. Analysis of the operation of penetration led the writer to believe that a layer of the aqueous solution must be established over part or all of the breathing pores and this layer over the breathing pores must be sufficiently thin to be drawn readily through the breathing pores with ingoing currents of air. Obviously, the establishment of a layer of aqueous solution over the breathing pores involved a sufficient reduction of the normal interfacial tension existing between it and the integument of the insect to permit ready wetting of the integument. Obviously also, the production of a layer sufficiently thin to permit its inhalation required a decided reduction in the normal surface tension of the aqueous solution.

Since the factors of interfacial and surface tensions seem to underlie a solution of the problem of introducing the aqueous solution into the breathing system of insects it was decided to devote attention, first, to one and then to the other phase.

STUDY OF INTERFACIAL TENSION EXISTING BETWEEN THE AQUEOUS SOLUTION AND THE INTEGUMENT OF INSECTS

Application of the term "interfacial tension" to the relation existing between the aqueous solution and the integument of an

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

insect may not be technically correct but it does serve to indicate in a general way the meaning the writer has in mind.

The insect selected for this test was the honeybee (*Apis mellifera*) because of its ready availability at all times. The bees were removed from the hive and anesthetized with ether. The abdomen was then removed, care being taken not to mutilate or in any way change its surface. The abdomen was then fastened with the tergal surface up and as nearly in a horizontal position as possible. A drop of the solution to be tested was placed in the center of this area. A small syringe that delivered a uniform drop about 2.04 cubic millimeters in volume was used to apply the material. Two diameters of the drop were taken at right angles to each other with an ocular micrometer in a binocular microscope. The average of these two diameters was used to compute the area of the integument that was wetted by the drop of solution. The shape of the drop, when in contact with the integument of the honeybee, was usually an irregular circle. The segmented structure of the abdomen sometimes interfered with the uniform spread of the solution in some directions.

In order that any relationship which might later appear to exist between surface tension and spread, the surface tension of the liquid used was always determined before the solution was applied to the integument of the insect. The surface tension[2] was determined by the rise of the liquid in a capillary tube. This method of determining surface tension was used through the entire study. The temperature of the liquid was determined at the time the measurement of surface tension was being made. All determinations were made at room temperature. The effect of this variation in temperature upon the results obtained was considered negligible, in view of the fact that the variation in surface tension, arising from the change in temperature, was smaller than the error allowed under controlled conditions for this method of determining surface tension.

[2] The formula $Y = \frac{r.h.s.g.}{2}$ was used in calculating the static surface tension of the liquid in dynes per centimeter. In this formula "Y" is equal to the static surface tension of the liquid in dynes per centimeter, "r" is equal to the radius of the capillary tube in centimeters, "h" is equal to height in centimeters in the tube to which the liquid rises, "s" is equal to the specific gravity of the liquid, and "g" is the value of gravity (981 dynes).

TABLE I

SUMMARY OF THE DATA ON THE SPREAD OF AQUEOUS SOLUTIONS ON THE INTEGUMENT OF THE HONEYBEE

No. of Bees Used	Material Used	Initial Area Covered by Drop[1]	Area Covered After 1 Minute	Area Covered After 5 Minutes	Area Covered After 10 Minutes	Surface Tension[2]	Temperature of Liquid[3]
5	Distilled Water	2.96	2.71	2.52	2.89	75.9	24.0° C
5	2% Sodium Oleate	3.65	14.19			28.4	27.0° C
6	1% Sodium Oleate	3.06	14.02	14.19		28.4	28.0° C
6	½% Sodium Oleate	3.00	8.78	14.19		27.4	26.0° C
5	2% Fish Oil Soap	1.89	6.38	11.90	14.19	31.6	26.0° C
5	1% Fish Oil Soap	1.55	4.59	6.93	10.62	30.5	25.5° C
5	½% Fish Oil Soap	2.38	4.53	7.65	9.33	30.5	26.0° C
5	Distilled Water saturated with nonylic acid	2.13	2.45	2.52	2.59	38.0	27.0° C

[1] Areas are given in square millimeters.
[2] Surface tension in dynes per centimeter.
[3] Temperature in degrees Centigrade.

The carrying liquid in all cases was distilled water. Many materials were tried but of them all, various soaps and nonylic acid gave some promise. The fish oil soap was a commercial brand with a content of about 63 per cent. water. Sodium oleate was a supposedly pure product, as nearly free from water (about 10 per cent. water) as could be obtained. The results of this study are set forth in table I.

The data in this table are graphically set forth in figure 1. The figures in the table and the lines in the figure show at once that the speed of coverage with all soap treated solutions is more rapid than with distilled water alone, that the sodium oleate solutions was greater than with the fish oil soap solutions. To make this conclusion yet more definite the relation between the fish oil soap and the oleic acid soap should be made still more clear. The sodium oleate carried about 10 per cent. water while the fish oil soap carried about 63 per cent. water. The sodium oleate soap was, therefore, 2.4 times as rich in soap as the fish oil soap. The 0.5 per cent. fish oil soap solution was actually 0.185 per cent. soap, the 1 per cent. fish oil soap solution was actually 0.37 per cent. soap, and the 2 per cent. was actually 0.74 per cent. The 2 per cent. fish oil soap should, therefore, be compared with the 1 per cent. sodium oleate solution and should, if it were an effective agent in promoting spread, fall between the curves representing 1 per cent. sodium oleate solution and 0.5 per cent. sodium oleate solution but as a matter of fact it falls much below the latter, indicating that sodium oleate, soap unit for soap unit, has greater power in expediting spread under the above conditions than has fish oil soap.

A curious and somewhat confusing result is found when the spread of distilled water is compared with the spread obtained with the nonylic acid treated distilled water. The speed of spread of nonylic acid treated distilled water was no greater and perhaps even a little less than the spread of distilled water alone, yet the surface tension was 38.0 dynes as compared with 75.9 dynes. This seems to prove that there exists no complete relation between static surface tension of the aqueous solution and its ability to spread over the insect integument. Furthermore, maximum reduction in surface tension was obtained in each kind

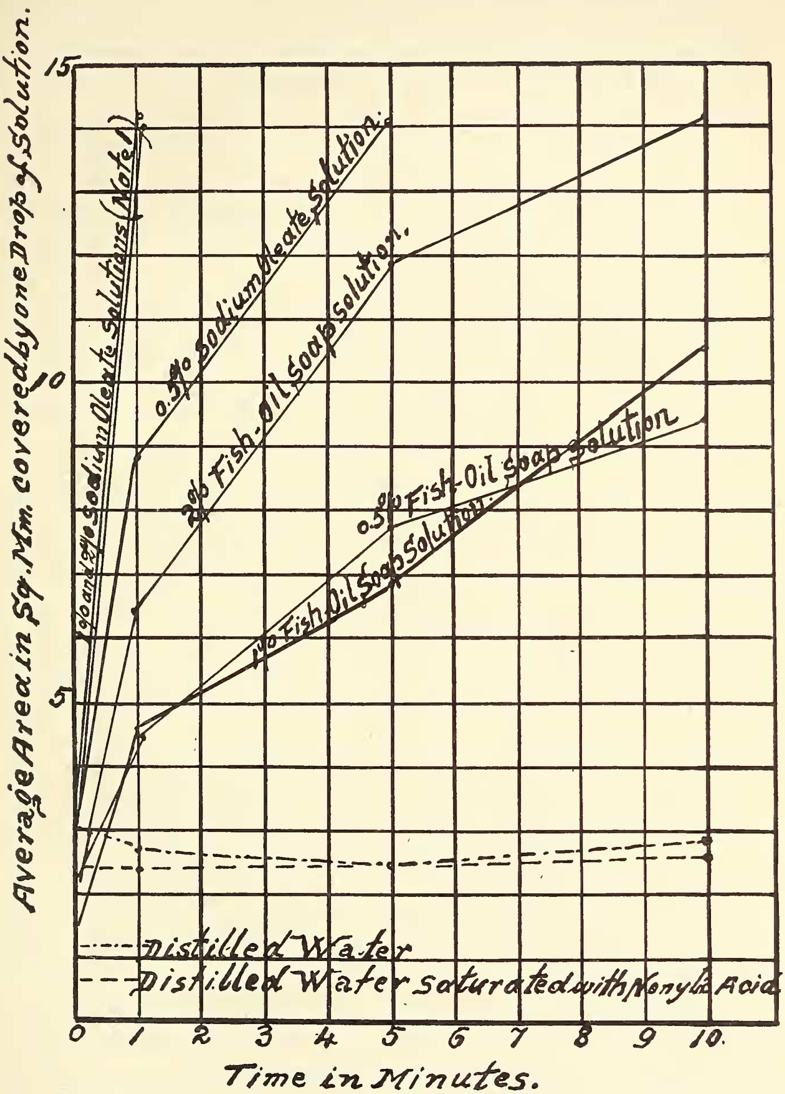

Figure 1. The spread of aqueous solutions on the abdominal integument of the honeybee.

of soap when as much as 0.5 per cent. was used, yet the speed of coverage was materially increased when twice as high a per cent. of the particular soap was employed. This seems likewise to support the idea that there does not exist a complete relationship between static surface tension and rate of spread of the aqueous solution over the insect's integument. When we recall the more or less known fact that the insect's integument is apt to be covered with wax and wax-like substances and that the interfacial tension between oils and water (1 and 4) is materially reduced by the addition of soap to the water, it seems at once reasonable that larger amounts of soap should give better wetting and consequently more rapid spread. Doubtless this effect of increased amounts of soap will vary with different kinds of insects because of the different types and amounts of wax and wax-like materials occurring on the integument.

Thus it seems; (1) that the addition of soap to distilled water increases the speed at which the treated aqueous solution can cover the integument of certain insects; (2) that within limits the greater the amount of soap the more rapidly does the coverage occur; (3) that this relationship holds even after the maximum degree in reduction of surface tension of the aqueous solution has taken place; (4) that surface tension, therefore, has no completely correlative relationship to interfacial tension.

Study of Surface Tension of Aqueous Solutions

In table I of the preceding section of this paper it has been noted that the ordinary surface tension of water is about 76 dynes and that by the addition of about 0.5 per cent. sodium oleate this surface tension may be cut as low as 27.5 dynes. When we recognize that kerosene, which has a surface tension of about 28.5 dynes, has been shown by Nelson (9) and others to enter the breathing system of certain insects it seems entirely probable that an aqueous solution, with a surface tension of 27.5 dynes, would be able to do likewise, especially if the interfacial tension of this solution had been so reduced that the insect's integument could be readily and quickly filmed.

In the previous section it has been shown that an aqueous solution treated with sodium oleate can and does wet and spread with great rapidity and in this section it has been pointed out that the surface tension of this sodium oleate treated aqueous solution is lower than kerosene. It seemed, therefore, entirely probable that the aqueous solution treated with sodium oleate would enter the breathing system when sprayed upon the insect in the usual fashion.

Penetration of the Breathing System by Aqueous Solutions of Various Surface Tensions and Various Interfacial Tensions

To determine actual penetration it was, of course, necessary to utilize a dye. Anilin blue was selected as the dye because its solubility in water was sufficient to give to the aqueous solution a pronounced blue color.

The honeybee was again employed as the insect because of its availability and because of the large size of its propodial spiracle. The bees were removed from the hive and fed sugar and water. They were then placed in a clamp that held them in position so that the propodial spiracle could be observed with a binocular microscope. The propodial spiracle of the honeybee is 0.23 millimeters along the greatest diameter and 0.06 millimeters along the shortest diameter. It is oval in shape and bears a ridge along its anterior margin (12). The membranous valve is plainly visible and its movements can be detected with a microscope. The pubescence on the thorax of the honeybee is so dense around the spiracles that it was necessary to remove it in order to see the valve of the spiracle clearly. The movements of the spiracular valves varied. In some specimens the valve would only flutter slightly, as though air were rushing by it, and never open wide. In others it would open only slightly at the upper and lower corners, closing immediately. In still others the valve would be drawn completely to one side, leaving the spiracle wide open for as long as a second in extreme cases. These movements occurred in almost all possible combinations and rate of change from one type of movement to another. The spiracular valve in some specimens examined could not be observed to move even when watched continuously for three or four minutes. Possibly, confining the bees in the small wood and wire clamps, which were used, interfered with the respiration of some specimens more than others, for the variation between the movements of the valve of the spiracle of different specimens was very striking.

A small drop of solution was placed directly over the spiracle and the movements of the liquid and the valve of the spiracle were observed. The legs and wings of the bee were held so that they did not interfere with the liquid covering the spiracular opening. As there was a possibility of the bees being mechanically injured when they were put into or removed from the clamp, no record was kept as to the length of time they lived after they were released. Eight lots of ten bees each were treated as described in table II.

TABLE II

THE ENTRANCE OF LIQUIDS INTO THE BODY OF THE HONEYBEE THROUGH THE SPIRACLES

Lot No.	Material Applied to the Insect	Surface Tension of the Liquid*	Entrance of the Liquid Through the Spiracle
1.	Distilled water	76.0	None
2.	0.03% free nicotine in distilled water	78.0	None
3.	0.05% free nicotine in distilled water	78.0	None
4.	0.1% free nicotine in distilled water	73.8	None
5.	0.2% free nicotine in distilled water	70.2	None
6.	1.0% free nicotine in distilled water	68.5	None
7.	1.0% sodium oleate in distilled water[A]	28.5	Slow
8.	Water white kerosene[B]	28.5	Rapid

* Surface tension is given in dynes per centimeter.

[A] and [B]. Both these materials show great rapidity of spread over the insect's integument and presumably have low interfacial tension with the integument.

Solution used in lots 1 to 6, inclusive, in Table II, consisting of distilled water, and of distilled water containing various strengths of free nicotine derived from "Black Leaf 50," remained in hemispherical drops covering the spiracle. The area covered by these solutions increased in size very slowly and diminished as soon as appreciable amounts of water had evaporated. The spiracular valve continued to open and close under the drop but no material could be observed entering, even when the valve was wide open. In lots 7 and 8, the liquids, consisting of 1 per cent. sodium oleate in lot 7 and water white kerosene in lot 8, spread out in a thin layer over the integument of the insect, the soap solution spreading slower than the oil. When the spiracular valve opened only slightly, the kerosene could be seen flowing rapidly in through the spiracle. The soap solution flowed in only slowly when the valve was open. The bees, treated with a 1 per cent. solution of free nicotine (lot 6) and those treated with kerosene (lot 8), were killed before the integument dried but the spiracular valve did not close. The valve action usually became very rapid and violent just before the insect died.

Lee (5) found the thoracic spiracle on the grasshopper to function as intake openings for respiration. If it can be assumed that the respiratory movements in the honeybee, as observed by Snodgrass (12), indicate that the same respiratory circulation occurs in the honeybee as in the grasshopper, it is possible that the material was drawn into the trachea by the reduced pressure within. The high surface tension of the distilled water and the nicotine solution (lots 1 to 6, inclusive) formed a surface layer that was strong enough to withstand the suction and the force of gravity acting upon it and none of the material could break through this surface "skin" and enter the trachea. In lot 7, 1 per cent. oleate was used and in lot 8 water white kerosene was employed. The layer of liquid formed over the opening of the spiracle was so weak that, when acted upon by the respiratory suction and pull of gravity it readily extended, allowing the liquid to flow into the trachea.

Thus it seems that, when the aqueous solution has its interfacial tension sufficiently reduced to permit rapid coverage of the insect's integument to occur and surface tension sufficiently reduced to permit this coverage to occur in a thin layer it is able to penetrate the spiracle and to enter the trachea connected therewith.

For the purpose of securing further proof of this penetration of spiracles by aqueous solutions, it was decided to treat honeybees while alive with an aqueous solution, the surface and interfacial tension of which had been similarly reduced, and which had been charged with anilin blue.

Honeybees were removed from the hive and placed in small wire screen cages, five in each. These cages were paraffined to insure their not being toxic to the bees. Previous experiments carried out by Nelson (9) had proved that unparaffined screen cages were very toxic to honeybees. The bees were then sprayed with six cubic centimeters of spray solution. The spray was carefully applied with a hand atomizer so that each of the bees in the cage was completely covered. The spray was allowed to remain on the bees for a given length of time. The bees were then rinsed with distilled water to remove the stain from their external surfaces. This was a precaution to minimize the possibility of spray on the integument of the insect entering the tracheæ during dissection.

In preliminary trials it was found that by pulling off the head and prothorax of the honeybee two large tracheæ were exposed. These tracheæ open through the first thoracic spiracle, which is irregularly oval in shape and about 0.14 millimeters in length along its greatest diameter. This spiracle can not be firmly closed, but is protected by opening into a deep pocket which is covered by a flap-like covering of the pocket it opens into. (12.)

This method of dissection exposed the tracheæ rapidly and uniformly and minimized the amount of distortion. It rendered about 1.5 millimeters of the tracheæ visible.

As soon as the rinsing was completed the bees were partially dried as rapidly as possible by shaking the cage and then fanning it. They were dissected immediately and the results recorded. In this manner penetration into the tracheæ or spreading along the tracheal wall after the insect had died was largely prevented. Muscular reflexes occurred in most of the bees during and after dissection. Before dissection a drop of free nicotine was placed on the proboscis of any specimens that were too active to allow rapid observation of the tracheæ after dissection. The results of these tests are set forth in Table III.

TABLE III

THE PENETRATION OF AQUEOUS SOLUTIONS INTO THE THORACIC TRACHEÆ OF THE HONEYBEE

Lot No.	Material Used	No. of Bees Examined	Length of Time the Spray was Left on the Bees	Amount of Penetration into the Tracheae (Note 1)	Surface Tension of Liquid in Dynes in Cm.	Temperature of Liquid
1	2% Nicotine oleate and anilin blue	2	1 minute	Medium	29.0	22.5° C
	"	1	1 "	Slight	29.0	22.5° C
	"	2	1 "	None	29.0	22.5° C
	"	3	12 "	Heavy	29.0	22.5° C
	"	2	12 "	Medium	29.0	22.5° C
2	1% Nicotine oleate and anilin blue	5	1 "	None	29.5	21.5° C
	"	5	15 "	Heavy	29.5	21.5° C
	"	1	15 "	None	29.5	21.5° C
3	0.5% Nicotine oleate and anilin blue	2	15 "	Medium	28.5	20.5° C
	"	1	15 "	Slight	28.5	20.5° C
	"	2	15 "	None	28.5	20.5° C
4	0.25% Nicotine oleate and anilin blue	5	20 "	None	30.6	22.5° C
5	0.1% Nicotine oleate and anilin blue	5	20 "	None	32.7	22.5° C
6	0.05% Nicotine oleate & 0.25% para-cresol & anilin blue	5	15 "	None	33.7	22.0° C
7	0.25% Nicotine oleate & 0.5% para-cresol & anilin blue	3	15 "	Slight	30.8	22.0° C
	"	2	15 "	None	30.8	22.0° C

TABLE III—(*Continued*)

THE PENETRATION OF AQUEOUS SOLUTIONS INTO THE THORACIC TRACHEÆ OF THE HONEYBEE

Lot No.	Material Used	No. of Bees Examined	Length of Time the Spray was Left on the Bees	Amount of Penetration into the Tracheae (Note 1)	Surface Tension of Liquid in Dynes in Cm.	Temperature of Liquid
8	1.0% pinene emulsion, 0.25% nicotine oleate with anilin blue and orange red	5	15 minutes	None		
9	0.5% pinene emulsion, 0.25% nicotine oleate with anilin blue and orange red	5	15 "	None		
10	1.0% para-cresol and anilin blue	6	15 "	None	44.3	25.0° C
11	1.0% sodium hydroxide + cresol and anilin blue	3	15 "	None		
12	Concentrated sodium hydroxide + cresol + anilin blue	3	15 "	Medium	38.0	22.0° C
13	25.0% ethyl alcohol 0.5% cresol & anilin blue	4	15 "	None	38.0	26.5° C
14	Water saturated with nonylic acid & 0.1% free nicotine & anilin blue	10	15 "	None	61.3	25.0° C
15	0.5% meta-cresol and anilin blue	5	20 "	None	59.1	24.5° C
16	0.5% meta-cresol + nonylic acid + anilin blue	3	20 "	None	33.7	27.0° C

TABLE III—(*Continued*)

THE PENETRATION OF AQUEOUS SOLUTIONS INTO THE THORACIC TRACHEÆ OF THE HONEYBEE

Lot No.	Material Used	No. of Bees Examined	Length of Time the Spray was Left on the Bees	Amount of Penetration into the Tracheae (Note 1)	Surface Tension of Liquid in Dynes in Cm.	Temperature of Liquid
17	1% meta cresol + nonylic acid + 0.1% nicotine sulphate and anilin blue	5	15 minutes	None	38.0	22.0° C
18	0.5% para-cresol, water saturated with nonylic acid & 0.01% nicotine sulphate + anilin blue	5	15 "	None	34.0	25.0° C
19	1.0% carbolic acid water saturated with nonylic acid + 0.1% nicotine sulphate + anilin blue	3	15 "	None	30.6	24.0° C

Note 1

SLIGHT (penetration)—The dye appearing only near the integument close to the first thoracic spiracle.

MEDIUM (penetration)—The dye appearing in the full length that was visible of one large tracheæ or part way in both.

HEAVY (penetration)—Both main tracheæ stained throughout the entire length visible and possibly some stain in the smaller branches.

None (no penetration)—No dye appearing in the thracheæ of the insect.

This table indicates that only slight entrance can be obtained from a spray possessing a surface tension of over 38 dynes per centimeter. Appreciable penetration was brought about at this surface tension, however, when a concentrated solution of NaOH was used. In this case the sodium hydroxide probably reduced the interfacial tension possibly by saponification of some of the wax-like substances upon the integument of the honeybee.

Thus in this series of tests there appears clear and distinct proof that when both surface and interfacial tensions of the aqueous solutions are reduced to the proper point, actual penetration of the breathing system occurs.

THE EFFECT OF USING AQUEOUS SOLUTIONS, CONDITIONED AS TO SURFACE AND INTERFACIAL TENSIONS AS SET FORTH IN THE PRECEDING PARTS OF THIS PAPER, UPON CERTAIN PLANT LICE WHEN USED EITHER WITH OR WITHOUT NICOTINE

Sodium oleate, having proven to be an efficient material for enabling aqueous solutions to penetrate the breathing system of the honeybee, and fish oil soap having been a widely used material for treatment of plant lice, the work of conditioning the aqueous solution for surface tension and interfacial tension was limited to these two agents. Distilled water was utilized as a check throughout. The number of individual plant lice used in each test was large in order to reduce, as far as possible, the effect of individual variations. These studies covered a period in which the variation of temperature did not much exceed 10° F., while atmospheric moisture was more or less variable. In view of the fact that atmospheric moisture has by past indications been shown to have little effect on the metabolism of plant lice it was not considered necessary to control this factor. All experiments were conducted in the laboratory at New Brunswick, New Jersey, and in no case were the insects subjected to direct sunlight. The temperatures were, therefore, temperatures of shade. The amount of material applied to the plant lice in all experimentts was that which was necessary to wet the bodies of the lice. The spray was applied with an atomizer. The average kill obtained with distilled water on the green apple aphis was 9.24 per cent.

The results of treatments of the cabbage aphis and green apple aphis with aqueous solutions of soap are set forth in Table IV. All soap figures are now based upon actual soap.

TABLE IV

STUDY OF THE RELATION OF AQUEOUS SOLUTION OF SOAP TO THE KILL OF APHIS

(Each determination involved from one hundred to several hundred aphids.)

	Per cent.	
Av. kill (Cabbage aphis) F. O. S.	1/16	7.4
	1/8	10.9
	1/4	15.0
	1/2	69.7
Av. kill (Cabbage aphis) S. O.	1/16	12.2
	1/8	10.3
	1/4	26.6
	1/2	94.7
Av. kill (Green apple aphis) F. O. S.	1/3	20.7
Av. kill (Green apple aphis) S. O.	1/6	28.9
	1/3	38.1
	1/2	96.0
	2/3	95.6
	1	91.8

Note:—F. O. S. = Fish oil soap.
S. O. = Sodium oleate soap.

This table seems to show that sodium oleate soap is more effective than fish oil soap and that approximately 0.5 per cent. is the most efficient dosage.

The next question was the effect of free nicotine as compared with nicotine sulfate. The amount of soap used was reduced in order that the kill might in all cases stay below 100 per cent. The work was done upon the cabbage aphis. The same methods of application were employed as set forth above. The results appear in table V.

This table indicates that free nicotine is more powerful than nicotine sulfate when used with the same strength of soap.

TABLE V

STUDY OF THE RELATION OF SOAP AND NICOTINE TYPES TO KILL CABBAGE APHIS

(Each determination involved from one hundred to several hundred aphids.)

	Average Per Cent. Kill
F. O. S. 1/6 Per cent. + N. S. (1 to 5000)	71.3
F. O. S. 1/6 Per cent. + S. F. (1 to 5000)	89.2
S. O. 1/6 Per cent. + N.S. (1 to 5000)	82.1
S. O. 1/6 Per cent. + F. N. (1 to 5000)	87.2

Note:—F. O. S. = Fish oil soap.
S. O. = Sodium oleate.
N. S. = Nicotine Sulfate.
F. N. = Free nicotine.

TABLE VI

STUDY OF RELATION OF VARIOUS STRENGTHS OF SOAP AND NICOTINE TO THE KILL OF GREEN APPLE APHIS AND CABBAGE APHIS

(Each determination involved from one hundred to several hundred aphids.)

On Green apple aphis	Per cent.
S. O. 1/6 Per cent. + F. N. (1 to 50,000)	71.5
S. O. 1/6 Per cent. + F. N. (1 to 25,000)	90.4
S. O. 1/3 Per cent. + F. N. (1 to 20,000)	83.4
S. O. 1/3 Per cent. + F. N. (1 to 17,500)	65.3
S. O. 1/3 Per cent. + F. N. (1 to 15,000)	84.7
S. O. 1/3 Per cent. + F. N. (1 to 12,500)	83.1
S. O. 1/3 Per cent. + F. N. (1 to 10,000)	91.7
S. O. 1/2 Per cent. + F. N. (1 to 50,000)	99.5
S. O. 1/2 Per cent. + F. N. (1 to 25,000)	87.6
S. O. 1 Per cent. + F. N. (1 to 25,000)	94.5
On Cabbage aphis	
S. O. 1/6 Per cent. + F. N. (1 to 20,000)	60.0
S. O. 1/6 Per cent. + F. N. (1 to 10,000)	78.2
S. O. 1/6 Per cent. + F. N. (1 to 7,500)	89.5
S. O. 1/6 Per cent. + F. N. (1 to 6,250)	90.3
S. O. 1/6 Per cent. + F. N. (1 to 5,000)	87.2

Note:—S. O. = Sodium oleate.
F. N. = Free nicotine.

The next problem attacked was that of nicotine dosage. In this study sodium oleate was the only soap used. The methods of application were the same as previously outlined and the percentage of soap represents actual soap. The results are set forth in table VI.

This table shows clearly that when 0.5 per cent. of sodium oleate soap is used very high dilutions of nicotine can be employed with lethal results to the plant lice treated. This points to the practical application of this study, namely, that when sodium oleate, which is cheap, is used at a strength as great as 0.5 per cent. the amount of nicotine necessary to effect lethal results on plant lice under summer temperatures is very small. It should be pointed out that this work upon aphids was done during hot weather in the latter part of the summer when the insect resistance was low and that this fact largely accounts for erratic results. Nevertheless, the general trend of the results is clear. Work done by Mr. Filmer in the spring of 1929, which will be published later, shows that the above trend can be utilized with striking results in practical orchard procedure against apple plant lice.

Summary and Conclusions

1. Distilled water or distilled water carrying nicotine extract, having a surface tension of 40 or more dynes per centimeter, did not penetrate into the tracheæ of the honeybee even though the the integument was wetted thoroughly.

2. A reduction of the interfacial tension existing between the aqueous solutions and the integument and of surface tension sufficient to permit rapid coverage of the integument with a thin layer enables the aqueous solution to penetrate the breathing system of the honeybee.

3. Incorporation of sodium oleate soap in amounts varying from 0.2 per cent. to 2.0 per cent. (actual soap) so reduced the interfacial tension and the surface tension of the aqueous solutions as to permit this phenomenon to occur.

4. Sodium oleate soap, soap unit for soap unit, is more efficient in accomplishing these reductions of interfacial and surface tensions than fish oil soap and either is more efficient for this purpose than any other substances with which the writer worked.

5. Free nicotine is a more efficient agent against certain plant lice for use with the above conditioned aqueous solution than nicotine sulfate.

6. The size of the lethal charge of nicotine for destruction of certain plant lice is very greatly reduced when it is incorporated in an aqueous solution, the interfacial and surface tensions of which have been reduced as set forth above.

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